

Trends in climate and snow in the (North)West

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With thanks to Dave Hart, Jon Lea, Greg Johnson, Randy Julander, Scott Pattee

<ftp://ftp.atmos.washington.edu/philip/SNOWPAPER/>

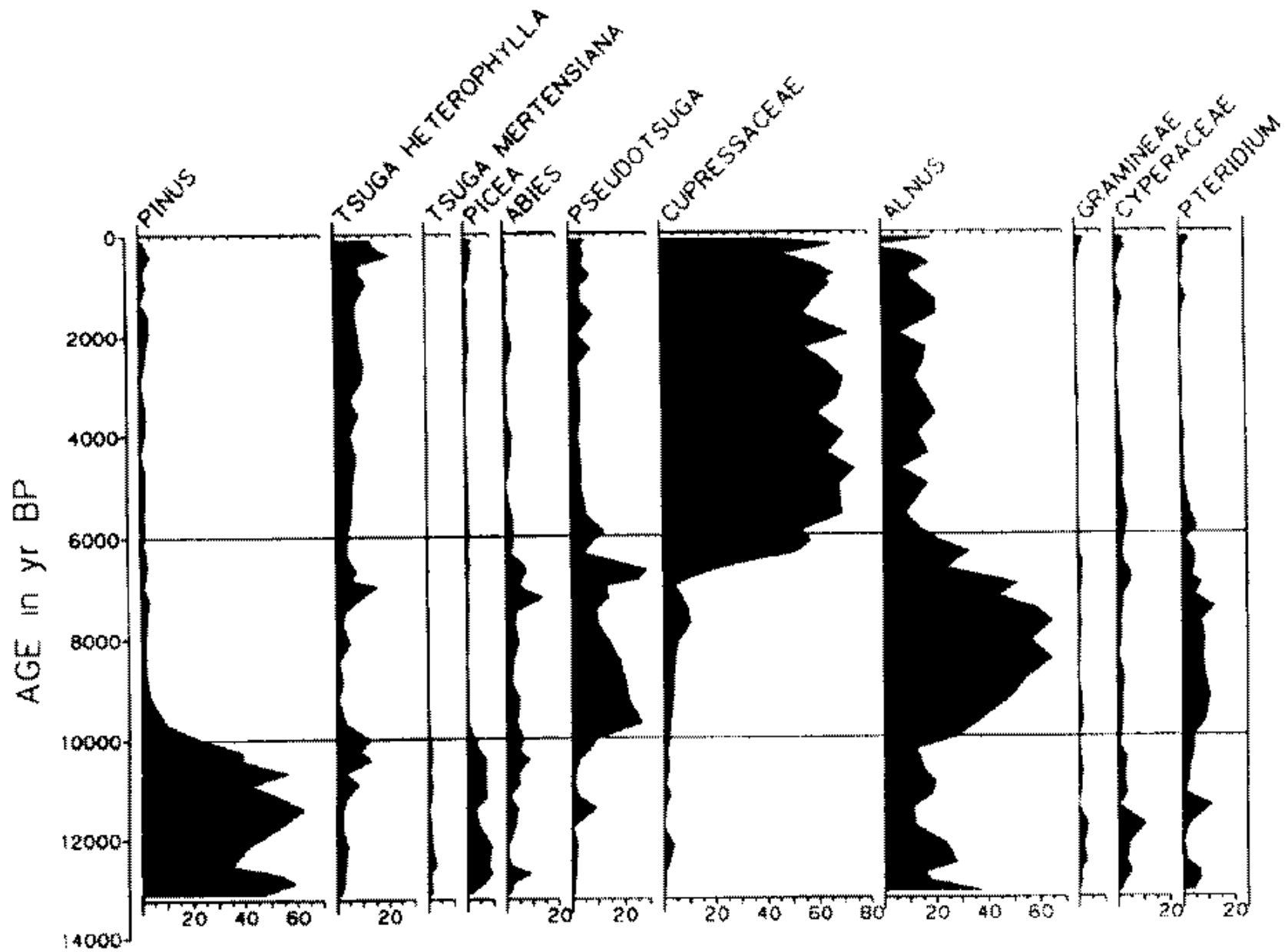






Ice Age Floods Institute

Pollen records on the Olympic Peninsula (Crocker Lake)



This talk

- Significant warming occurred in 20th c
- Precipitation is variable
- Snow reflects both temp and precip

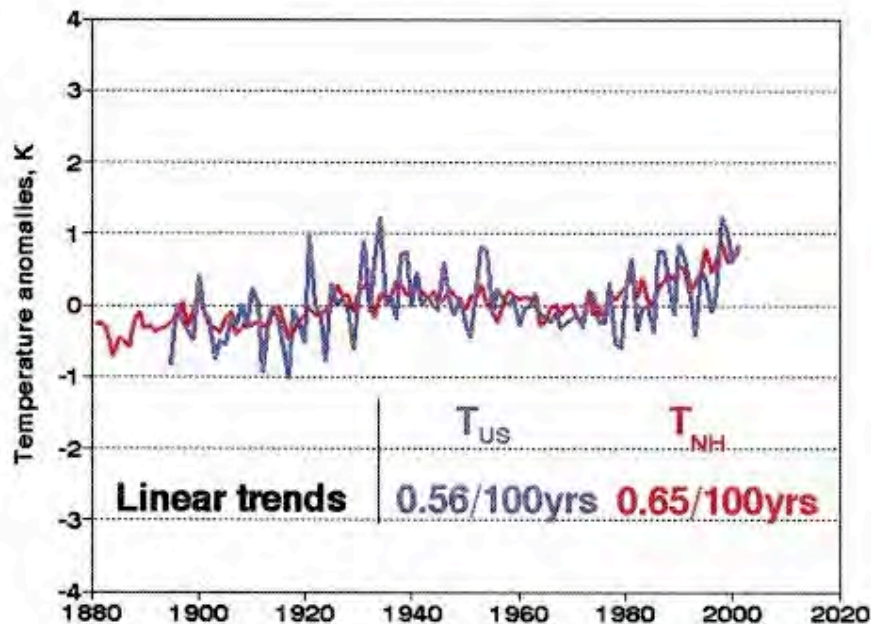


FIG. 3. Annual area-averaged temperature over the contiguous United States (1895–2002) based on the USHCN (T_{US} ; blue line) and over the Northern Hemisphere (1881–2002) (Lugina et al. 2003; T_{NH} ; red line). (Sources: <http://www.ncdc.noaa.gov/oa/climate/research/2002/ann/us-summary.html#Atemp> and <http://cdiac.esd.ornl.gov/trends/temp/lugina/data.html>.)

Groisman et al., 2004

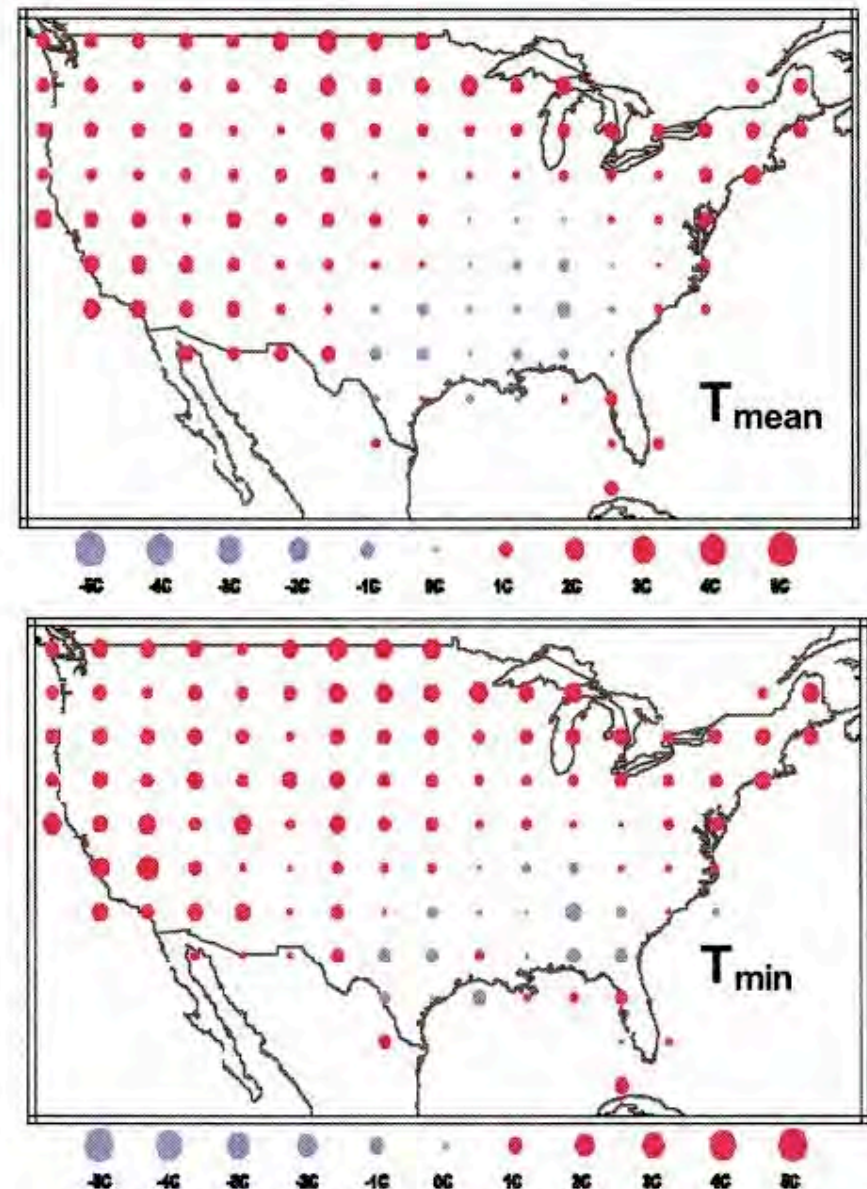


FIG. 4. (top) Annual mean (T_{mean}) and (bottom) minimum (T_{min}) temperature trends for the past century (1900–2002). Individual trends from USHCN stations have been area averaged within a $2.5^\circ \times 3.5^\circ$ grid. Red dots indicate increasing and blue dots decreasing trends. The dot areas are proportional to the trend values [$^\circ\text{C}/100$]

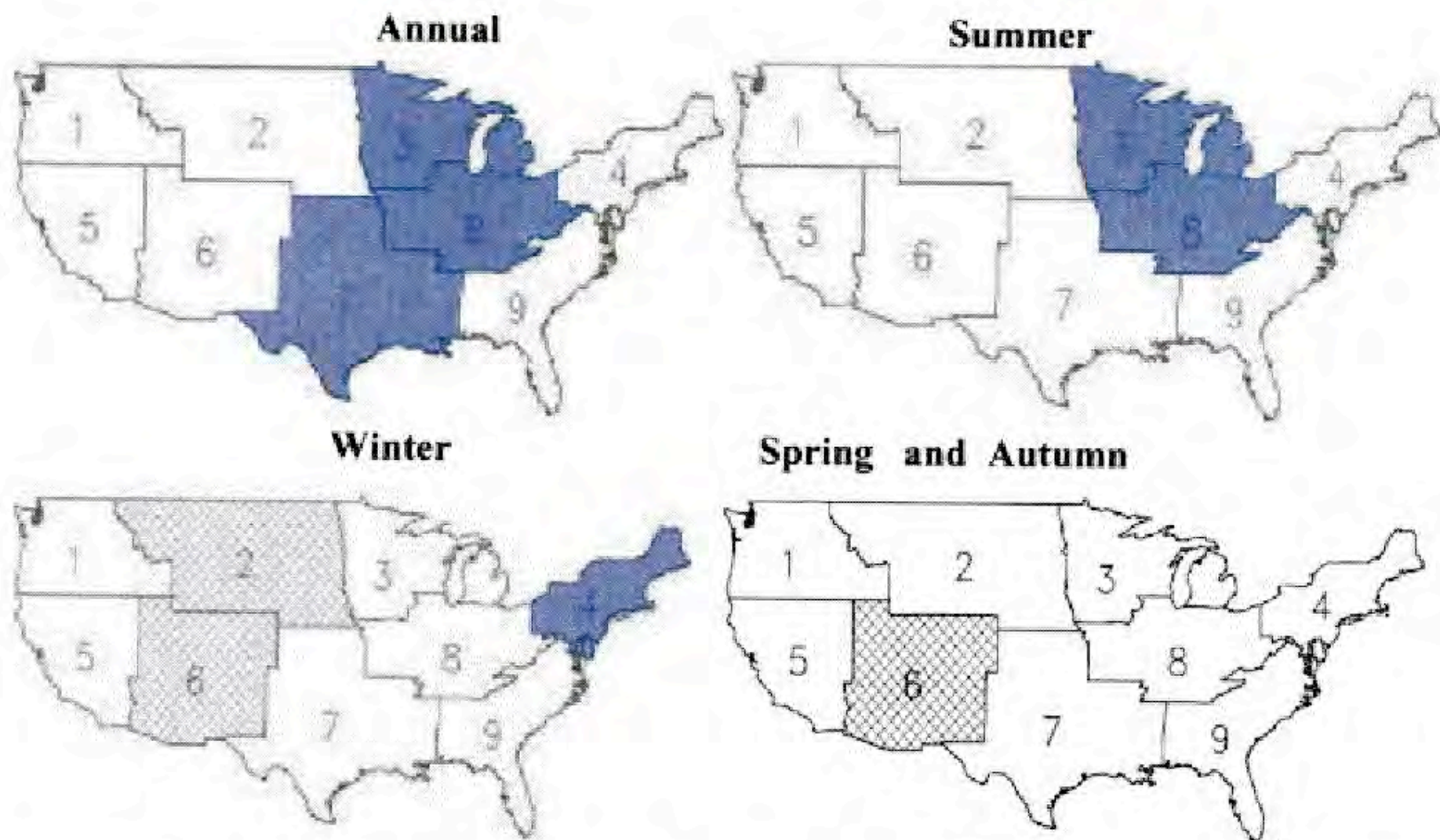
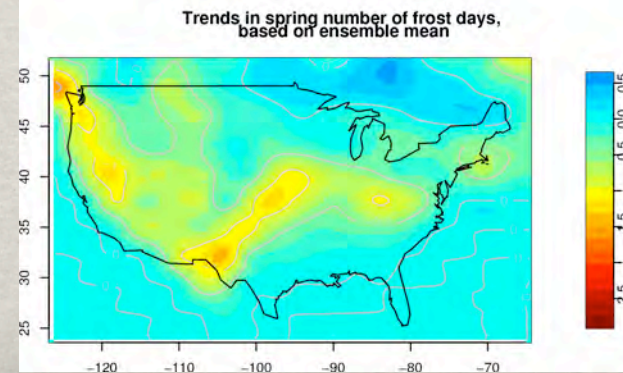
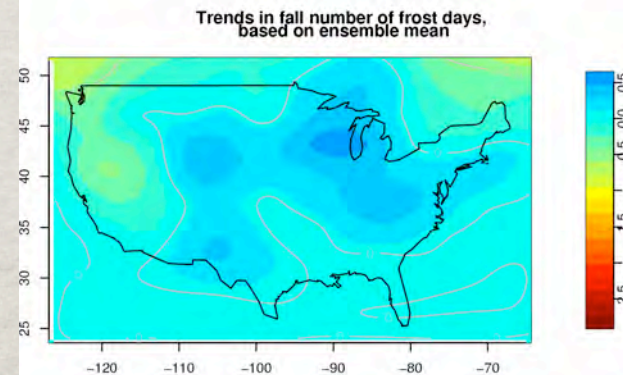
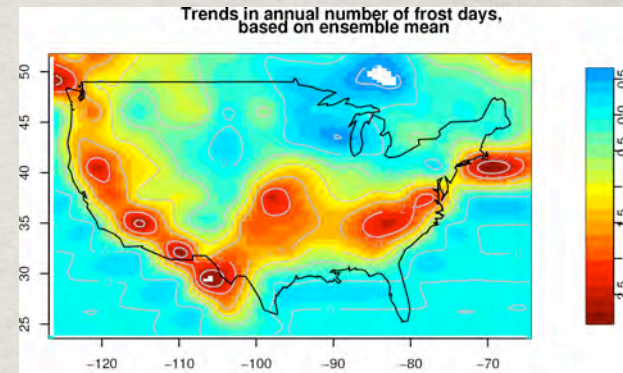
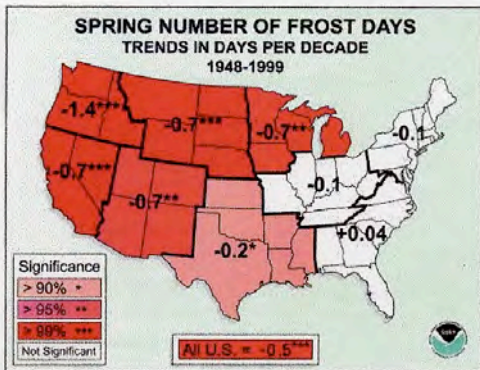
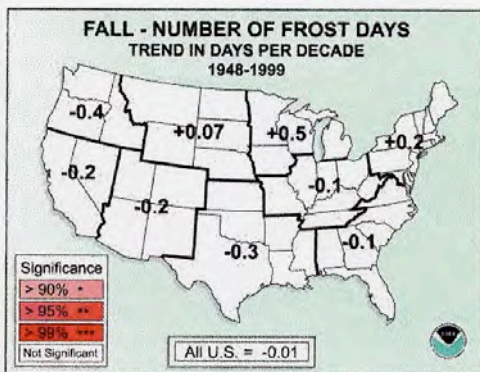
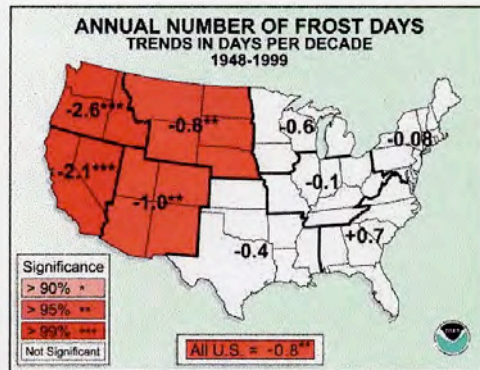
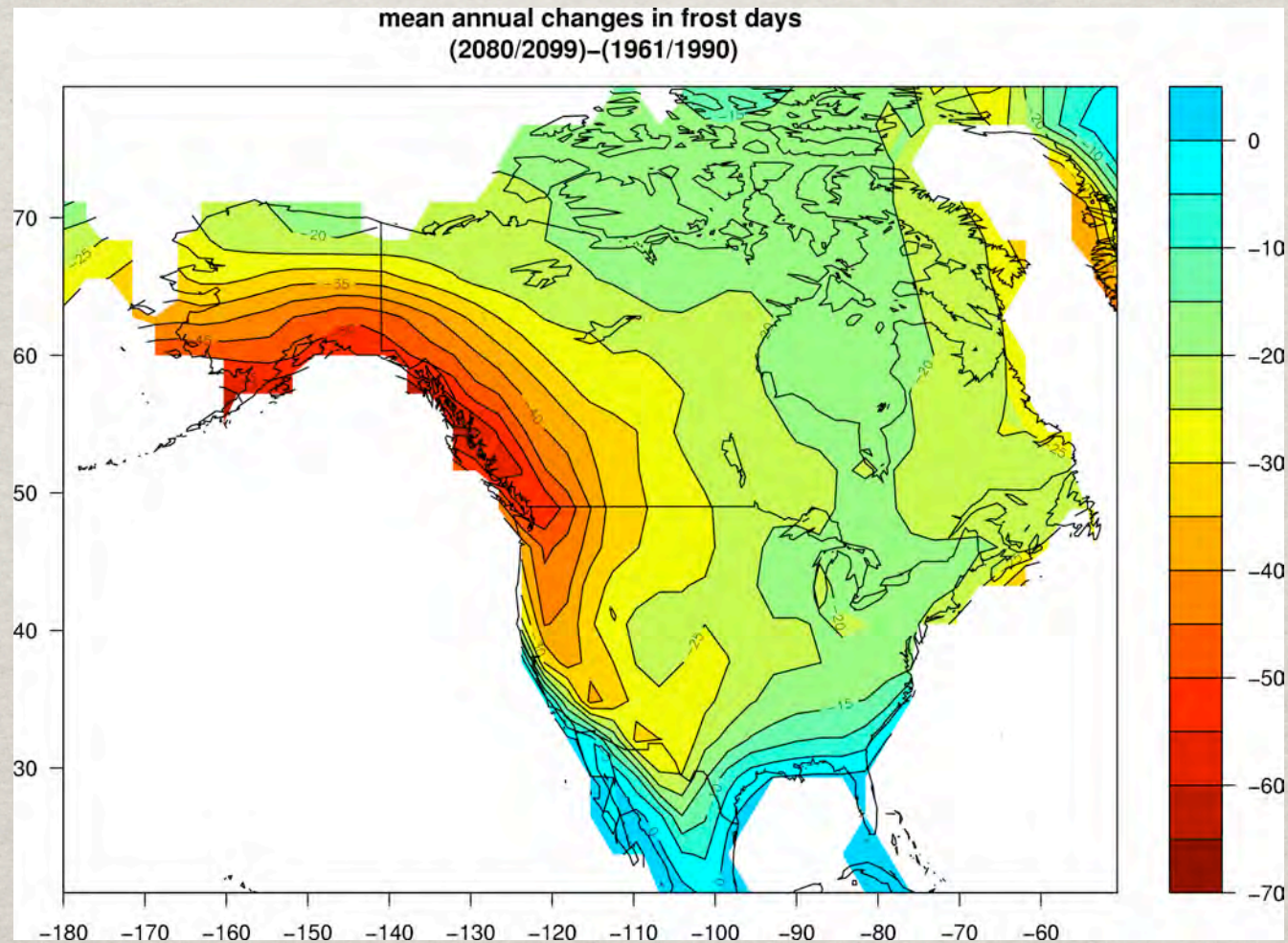


FIG. 8. Areas of significant trends in very heavy daily precipitation (above 99.7th percentiles) over the conterminous United States (1908–2000). Dark areas indicate increasing and hatched areas decreasing trends. Only trends that are statistically significant at the 0.05 significance level are shown. For seasonal precipitation, 99.7th percentile thresholds usually indicate daily rain events with a return period above 10 yr, while for annual precipitation it is in the range of 3–5 yr.

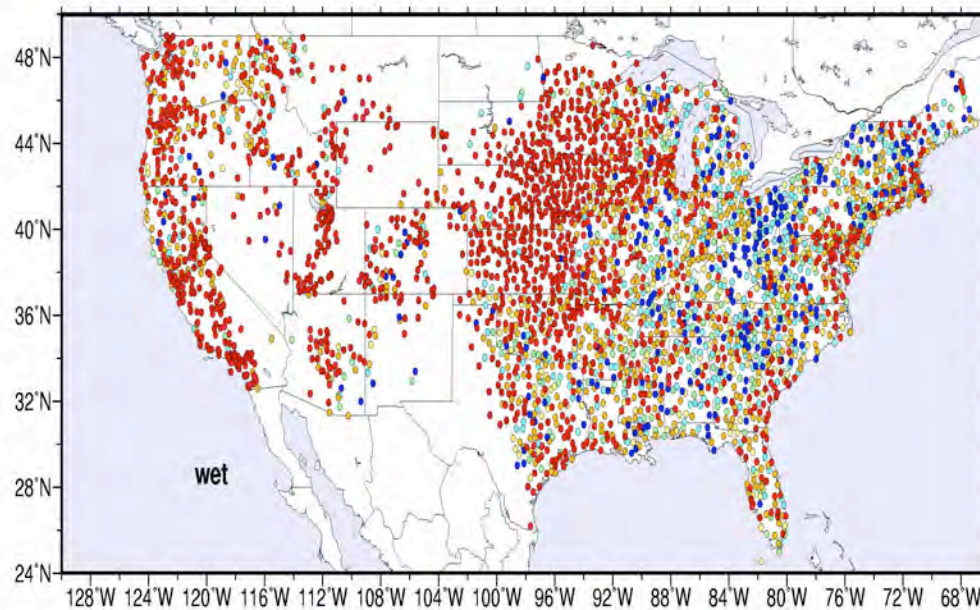
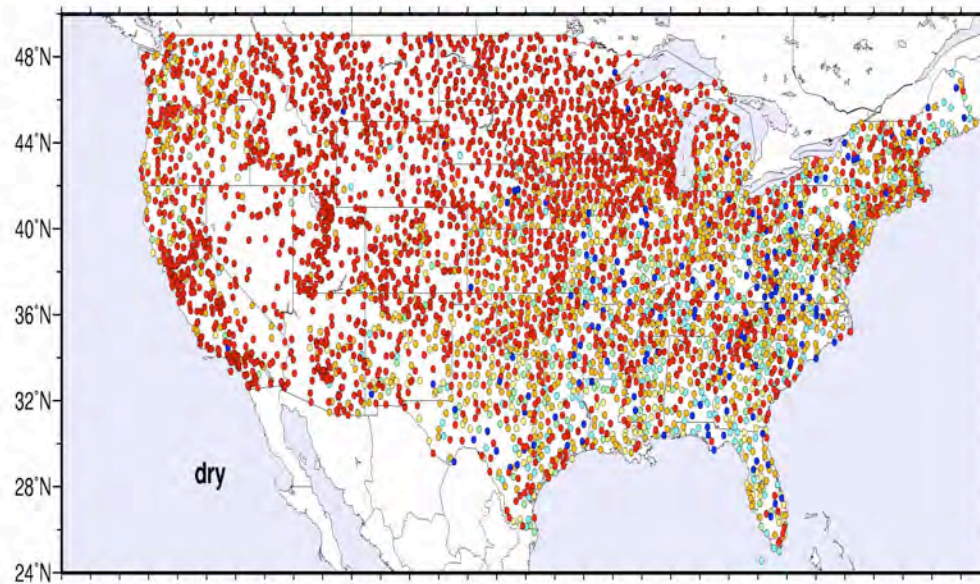
CHANGES IN FROST DAYS IN THE LATE 20TH CENTURY IN OBSERVATIONS AND THE PCM



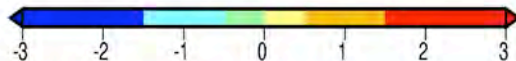
FUTURE CHANGES IN FROST DAYS FROM THE
PCM SHOW GREATEST DECREASES IN THE
WESTERN AND SOUTHWESTERN U.S., SIMILAR TO
LATE 20TH CENTURY



Trend Mar tmin dtra38



From NCDC daily data



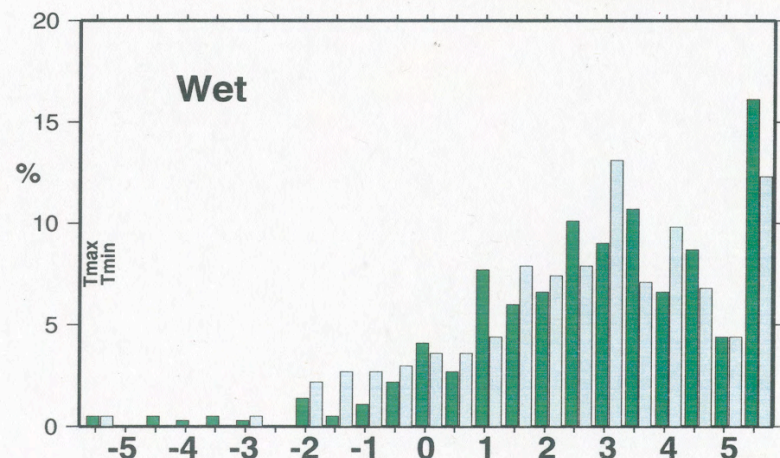
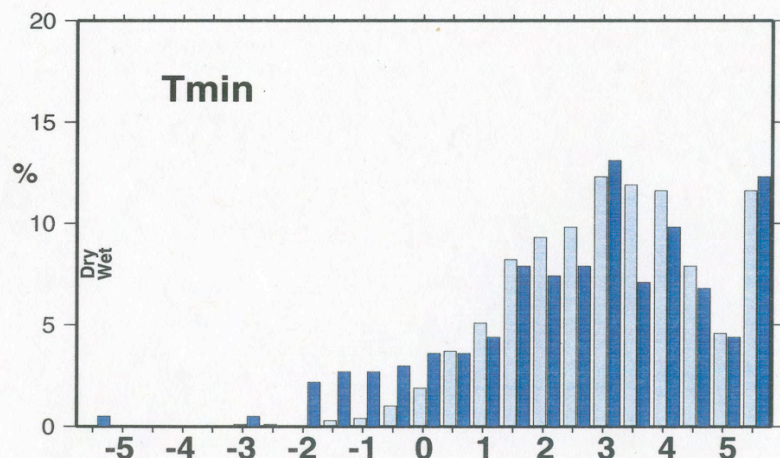
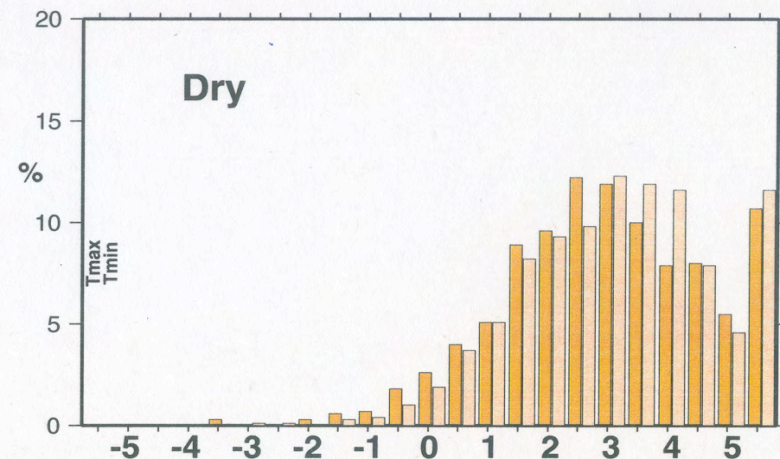
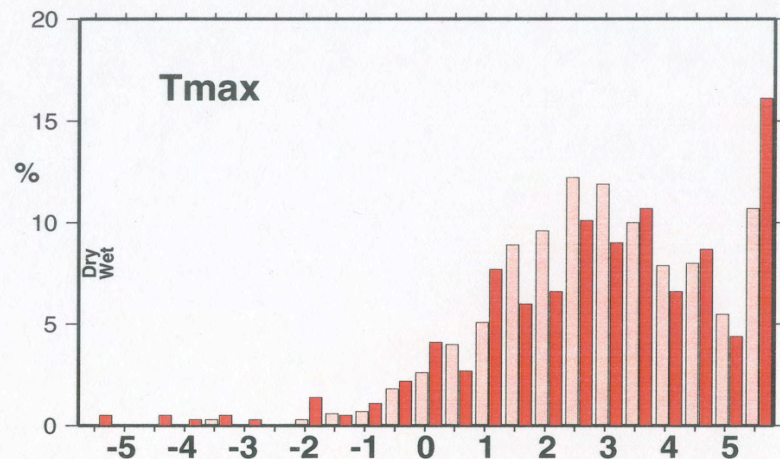
**Dry & Wet
days have
warmed
1950-2000**

**less snow, more rain
earlier snowmelt**

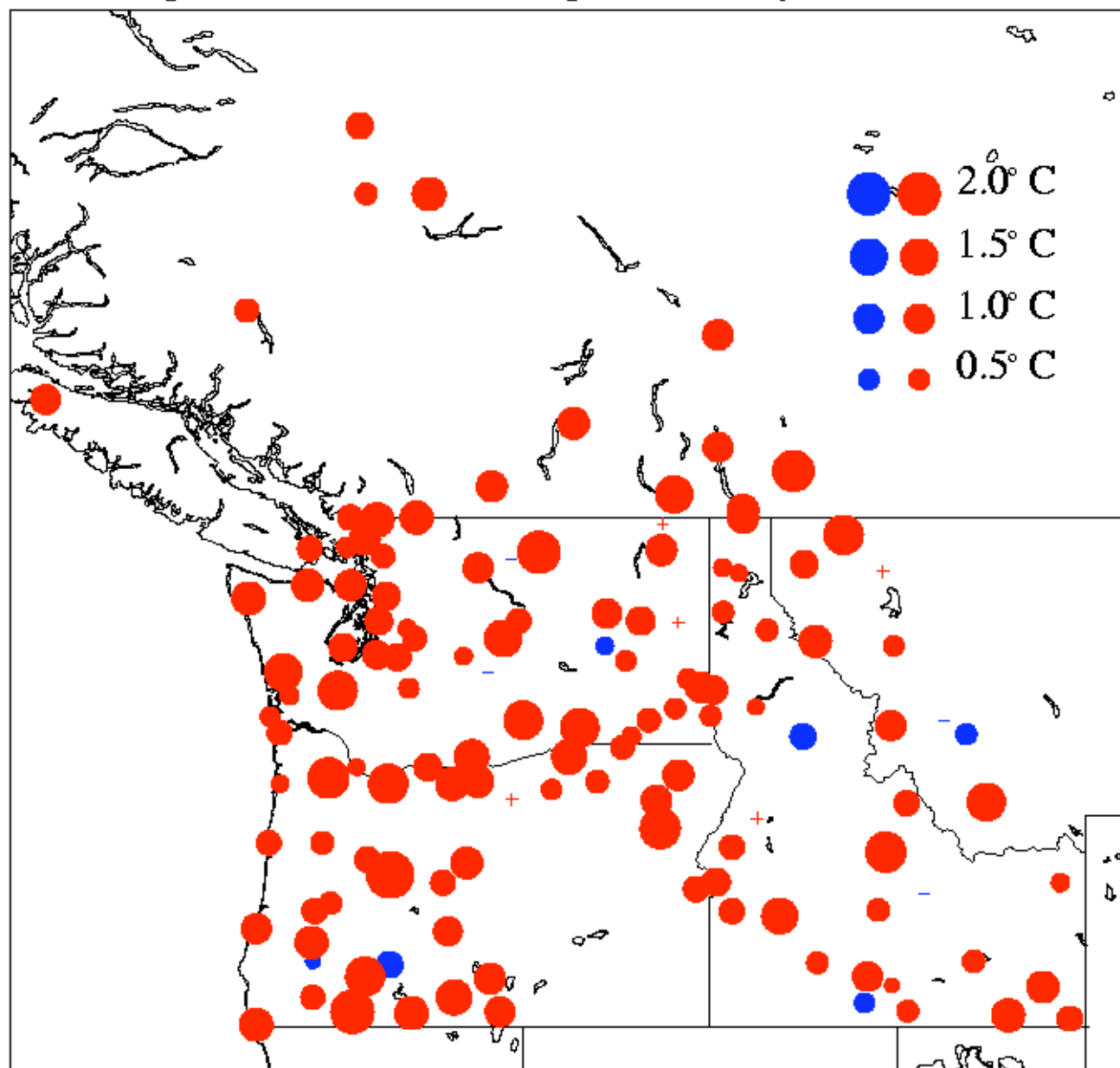
Distribution of Tmax and Tmin trends-- decidedly positive, wet/dry high/low

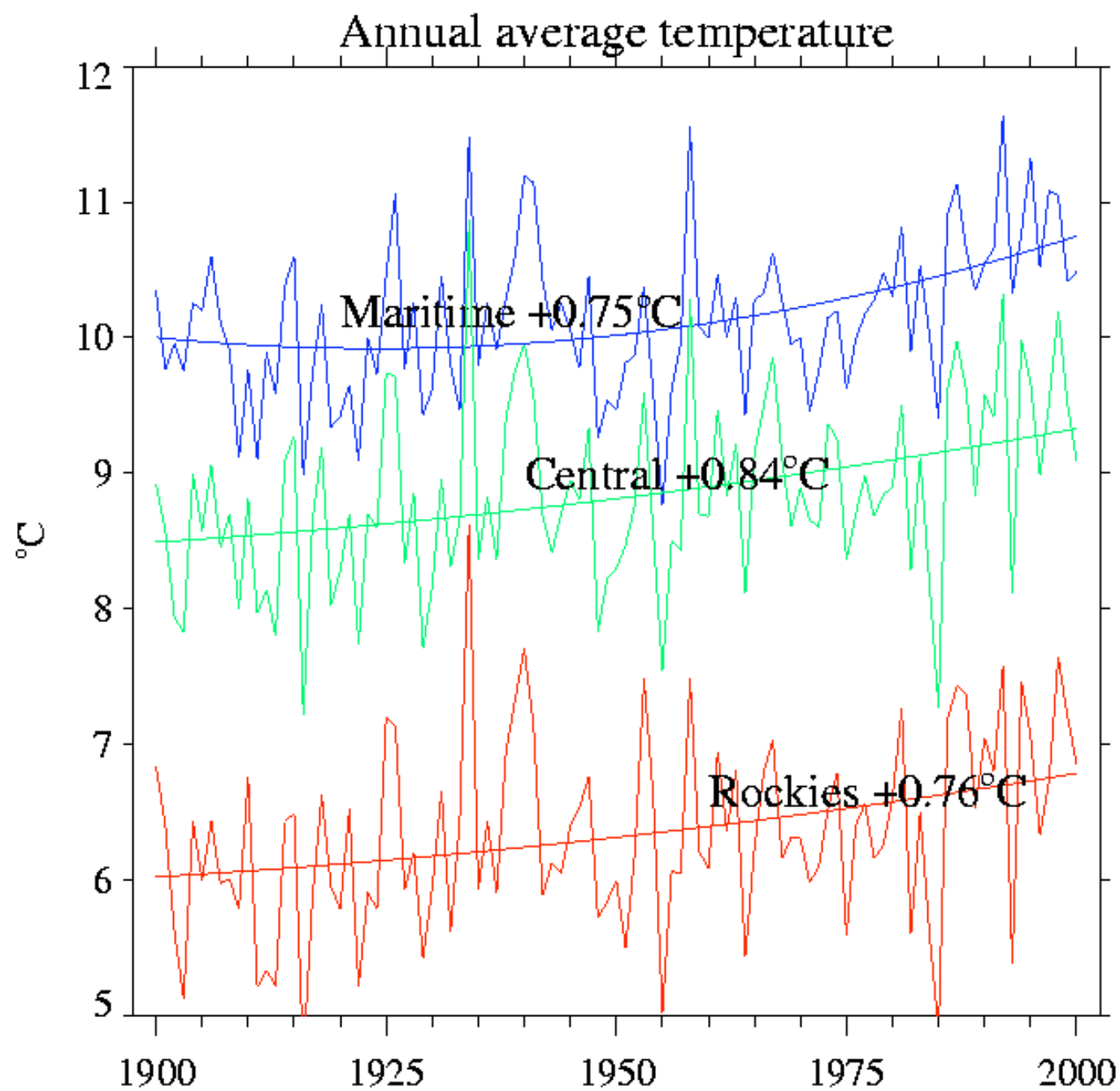
Change in temp over 50 years

Mar west hi elev 38

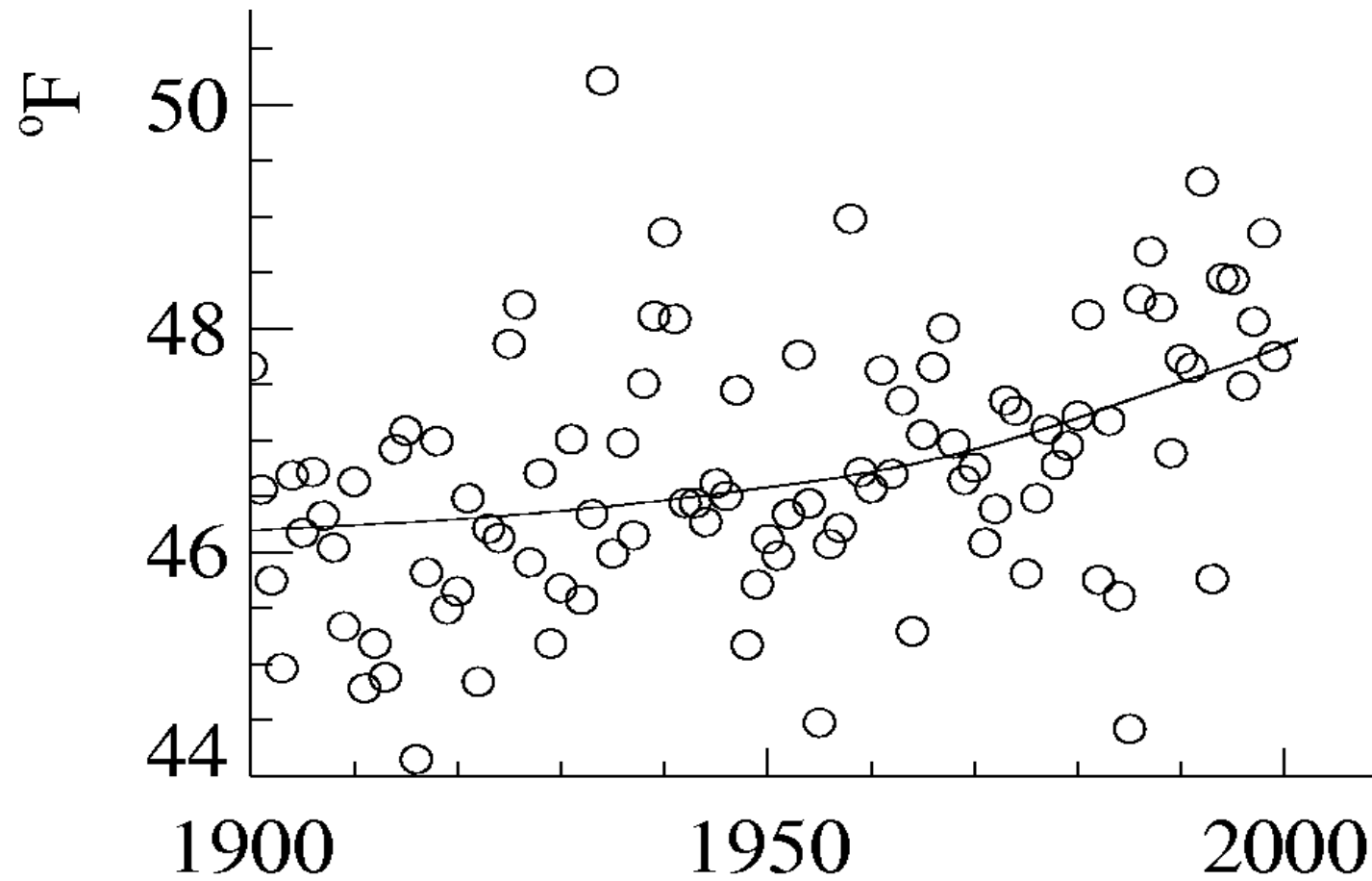


Temperature trends ($^{\circ}\text{C}$ per century), since 1920

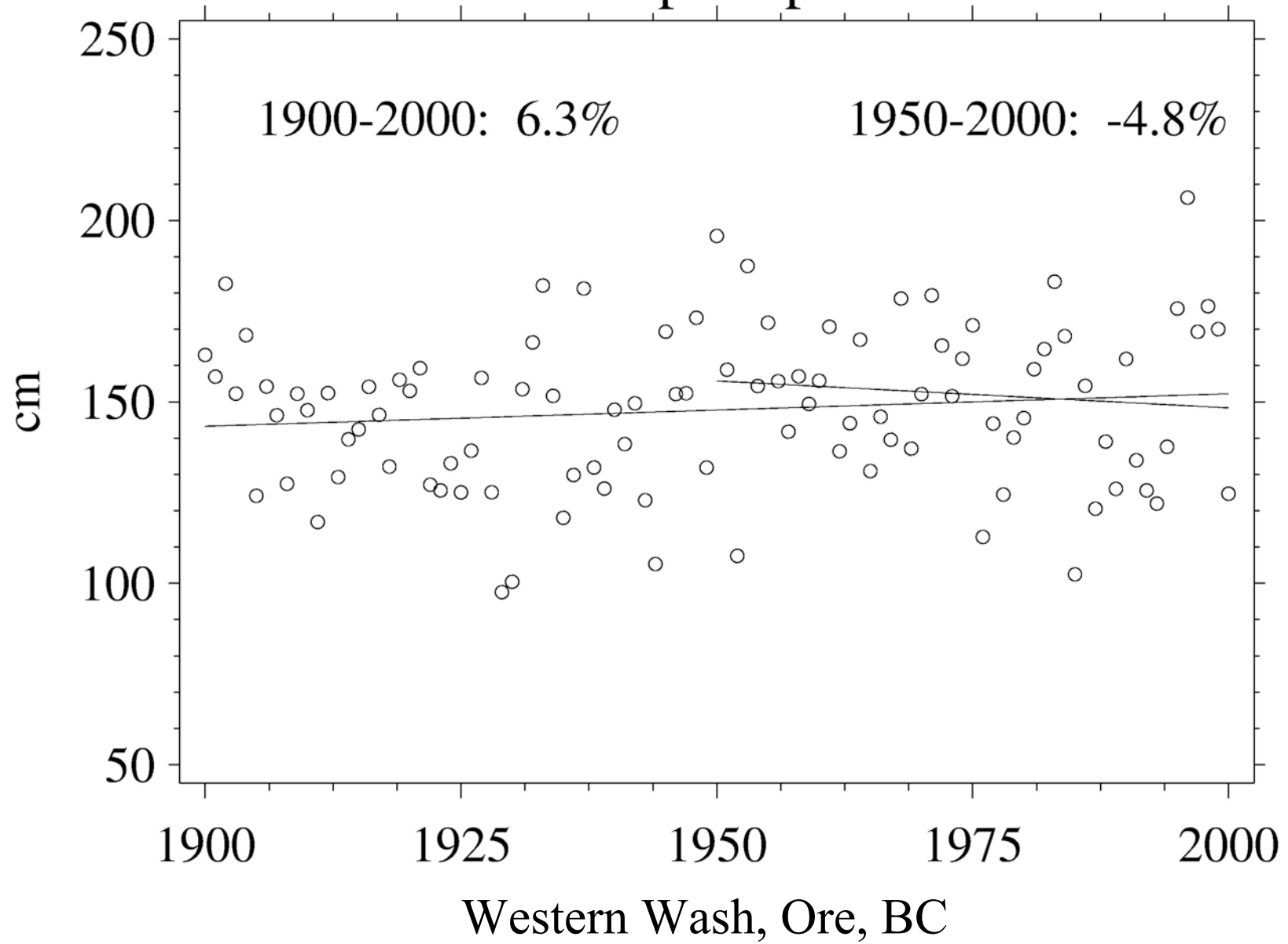




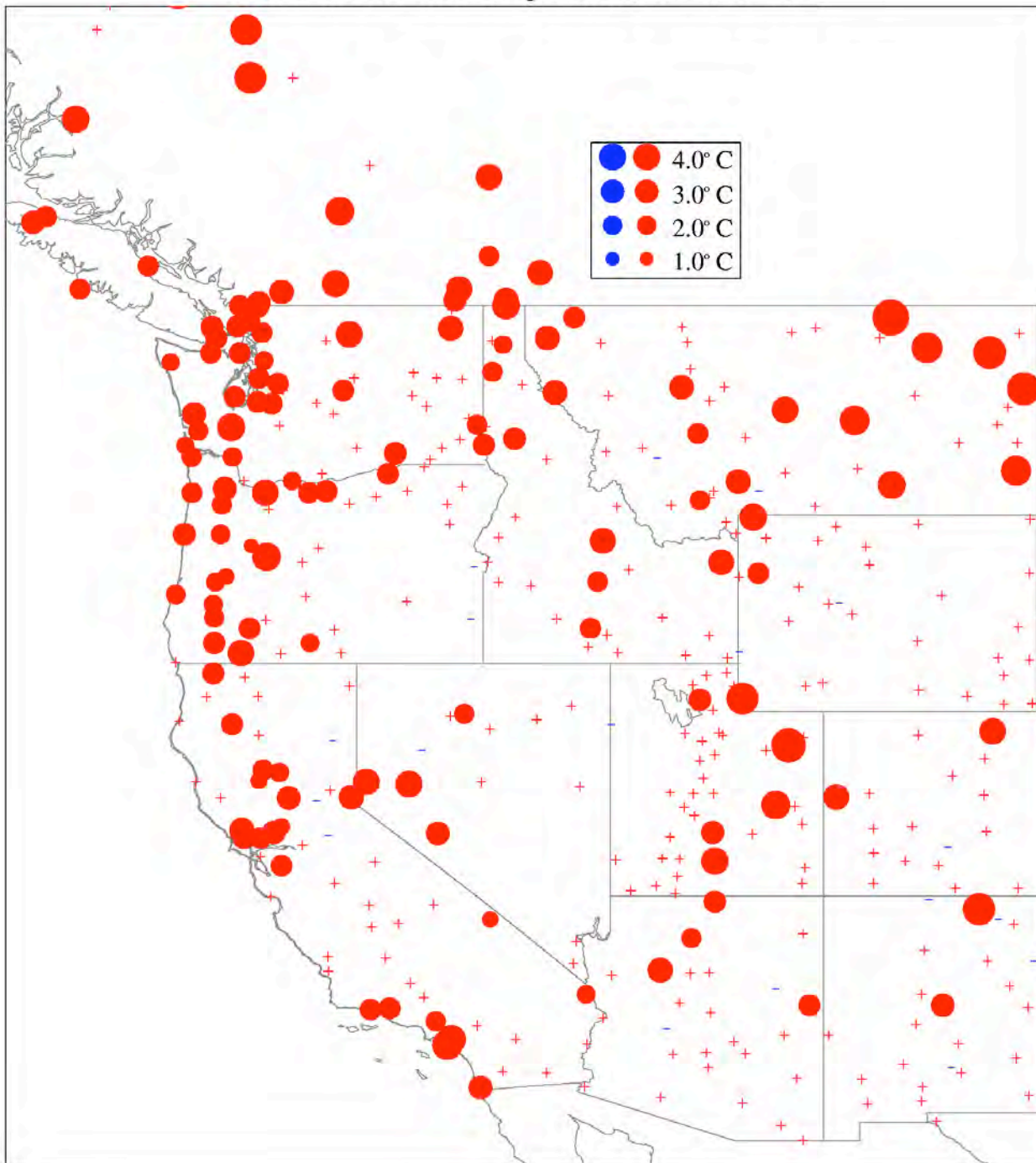
Northwest annual average temperature



Annual precipitation



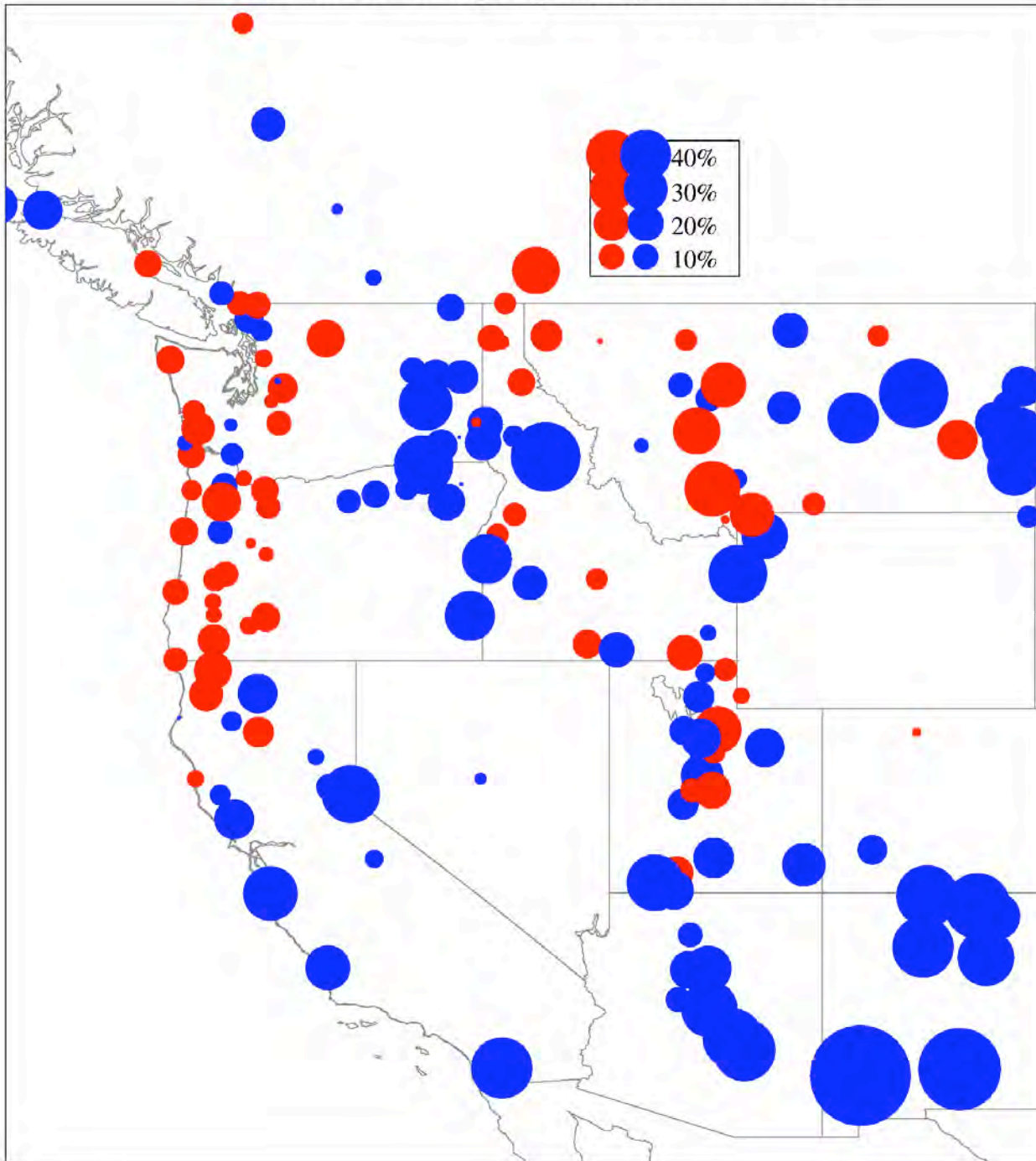
Trends in Nov-Mar temperature, 1950 to 2000



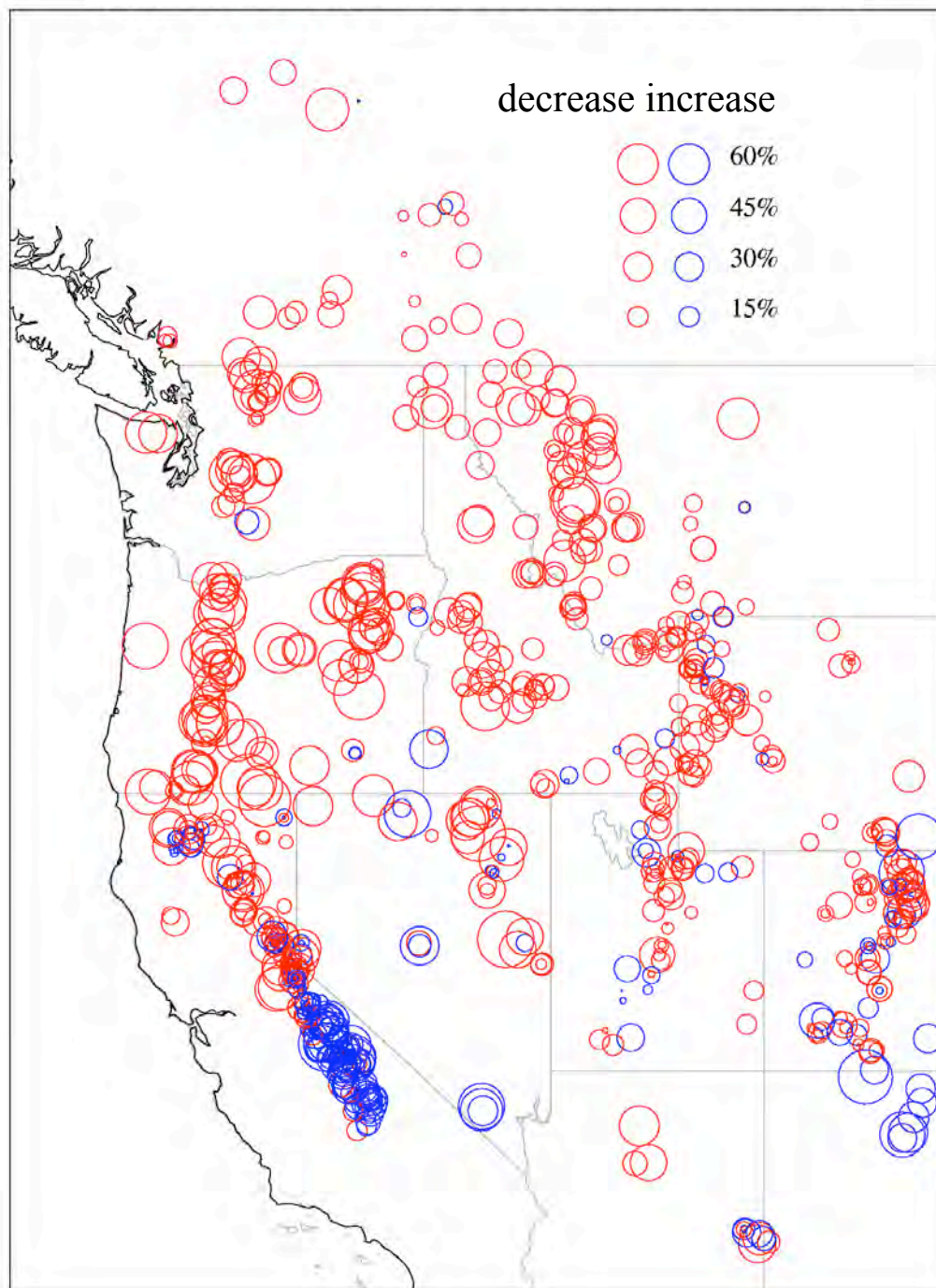
At almost every
USHCN station,
winters warmed

+ signs: warming
but not statistically
significant

Trends in Nov-Mar precipitation, 1950 to 2000



Winters wetter in
much of the West
Drier in some of
Northwest (PDO)



Data from NRCS, CA DWR,
BC SRM

824 snow courses/SNOTEL

Trends in April 1 SWE, 1950-
2000

Relative to 1950 value

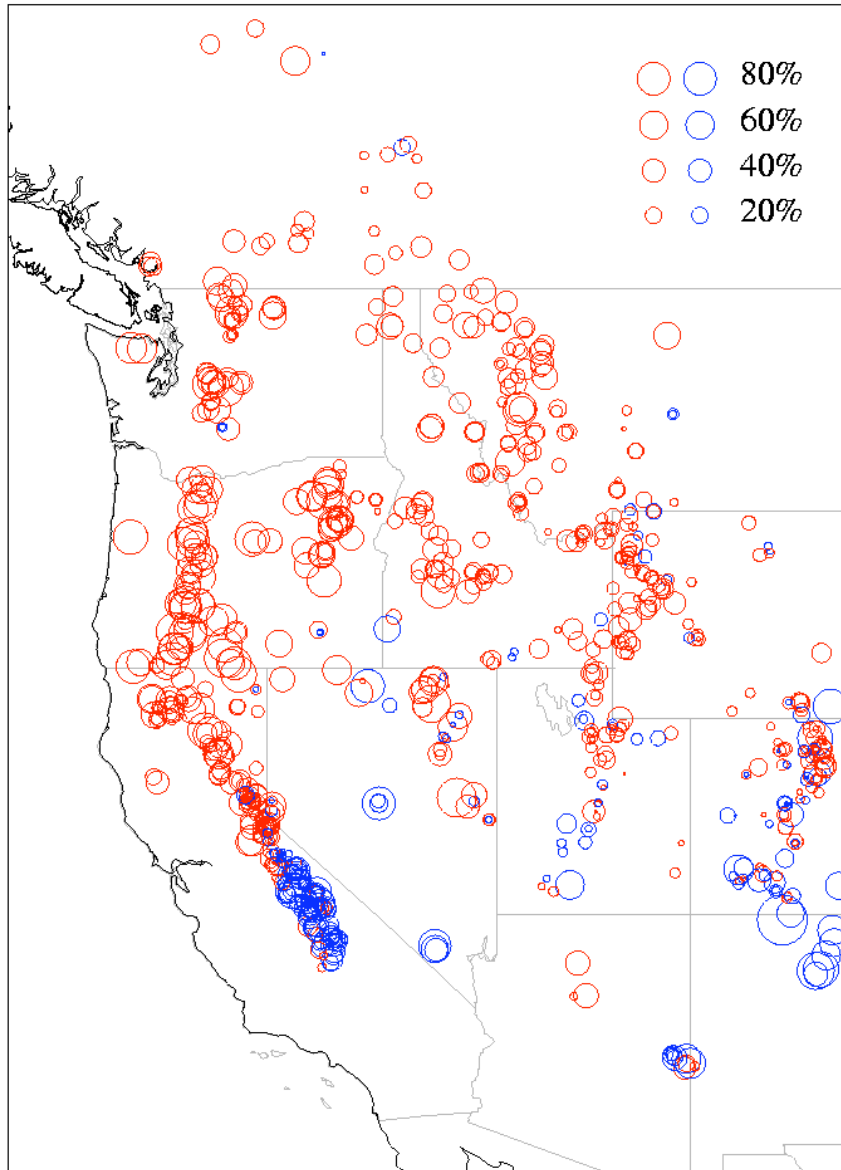
73% — trends

Large — trends PNW

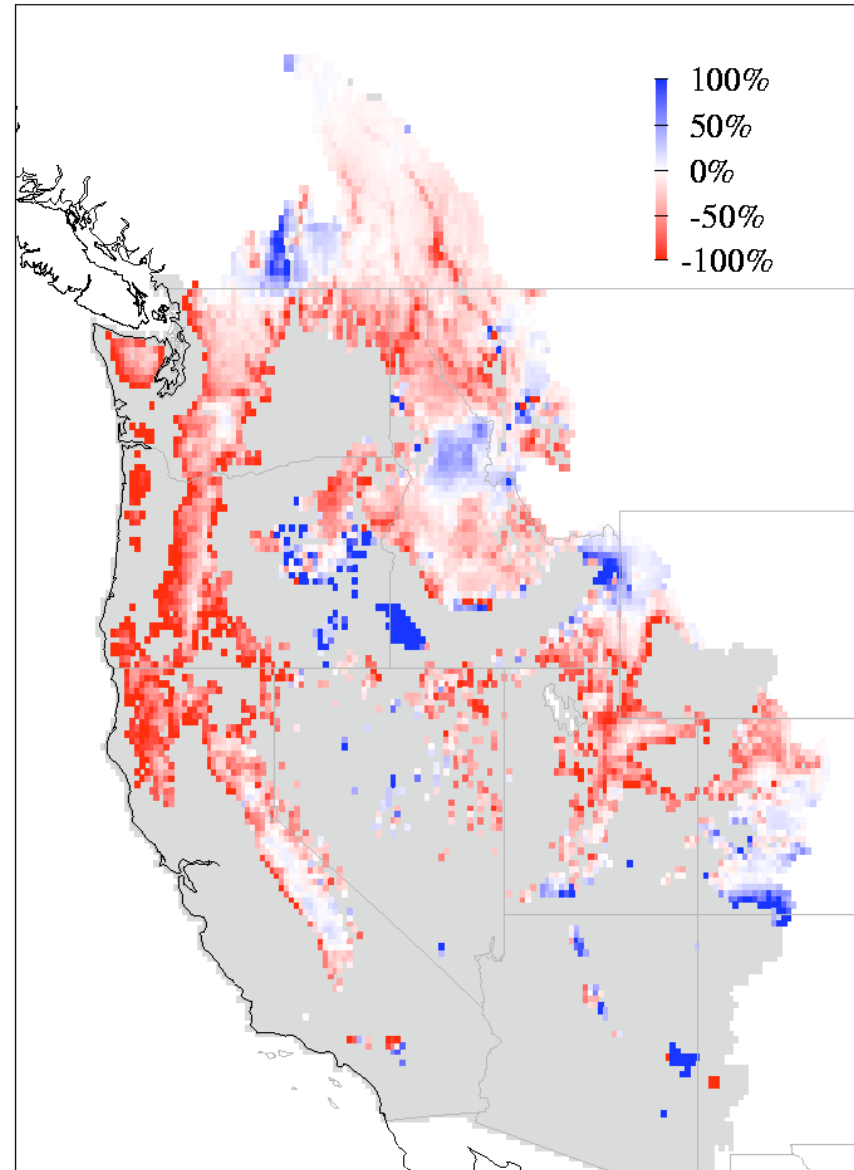
Some + trends SW

Relative trends 1950-1997

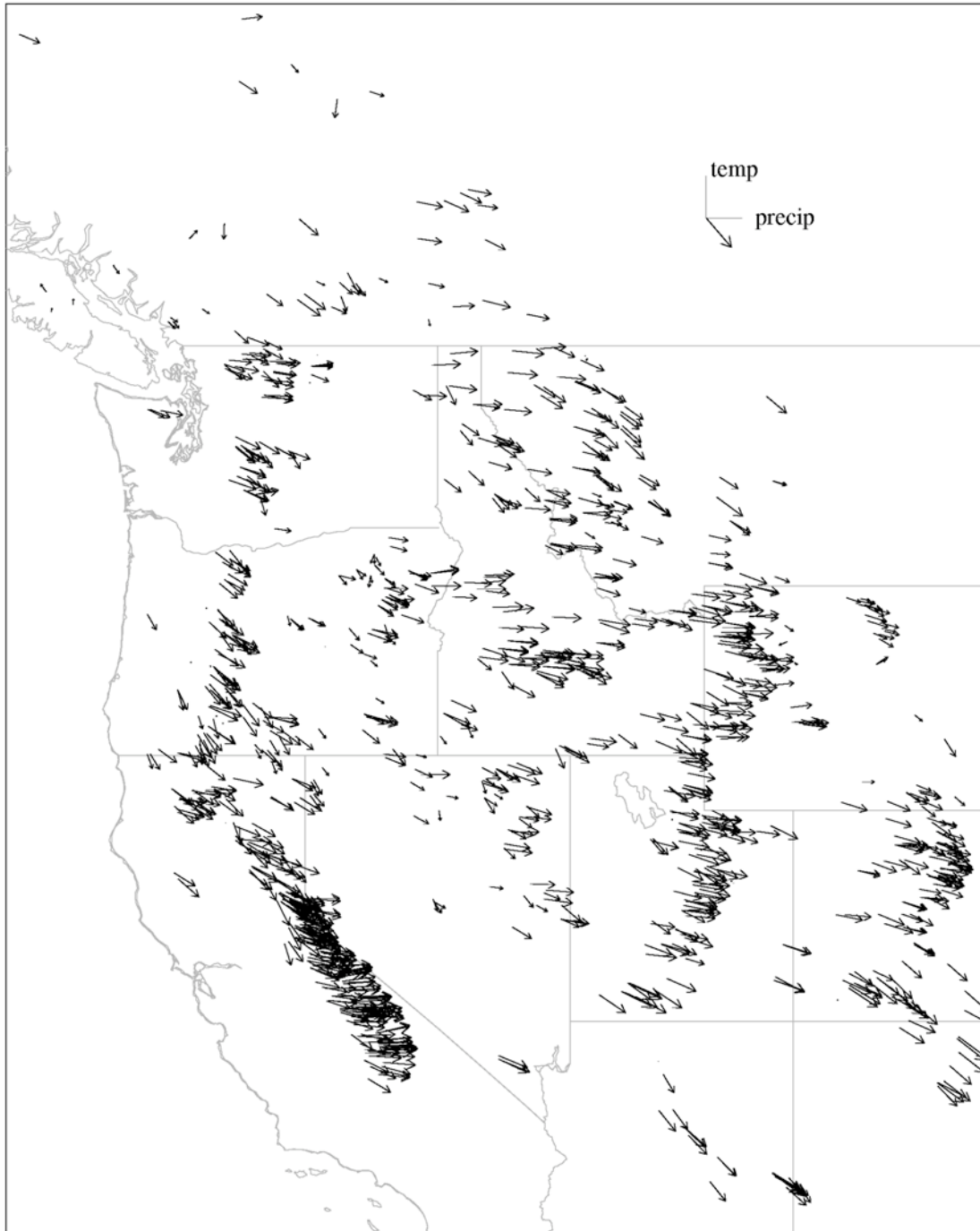
a. Observations



b. VIC



(r1, r2), Apr1, 1960 to 2002



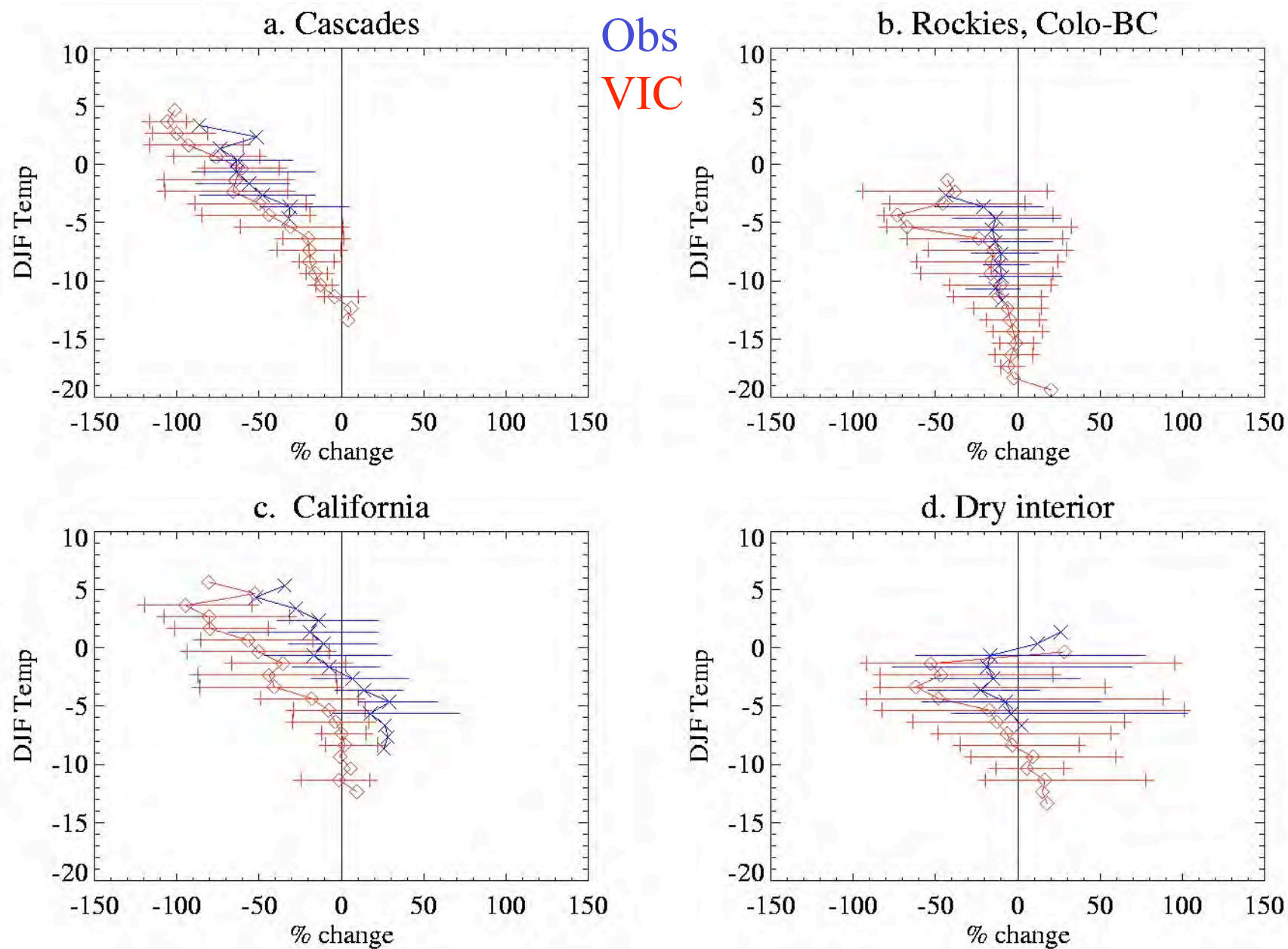
Correlations between Nov-Mar climate and Apr 1 SWE

X-direction: precip

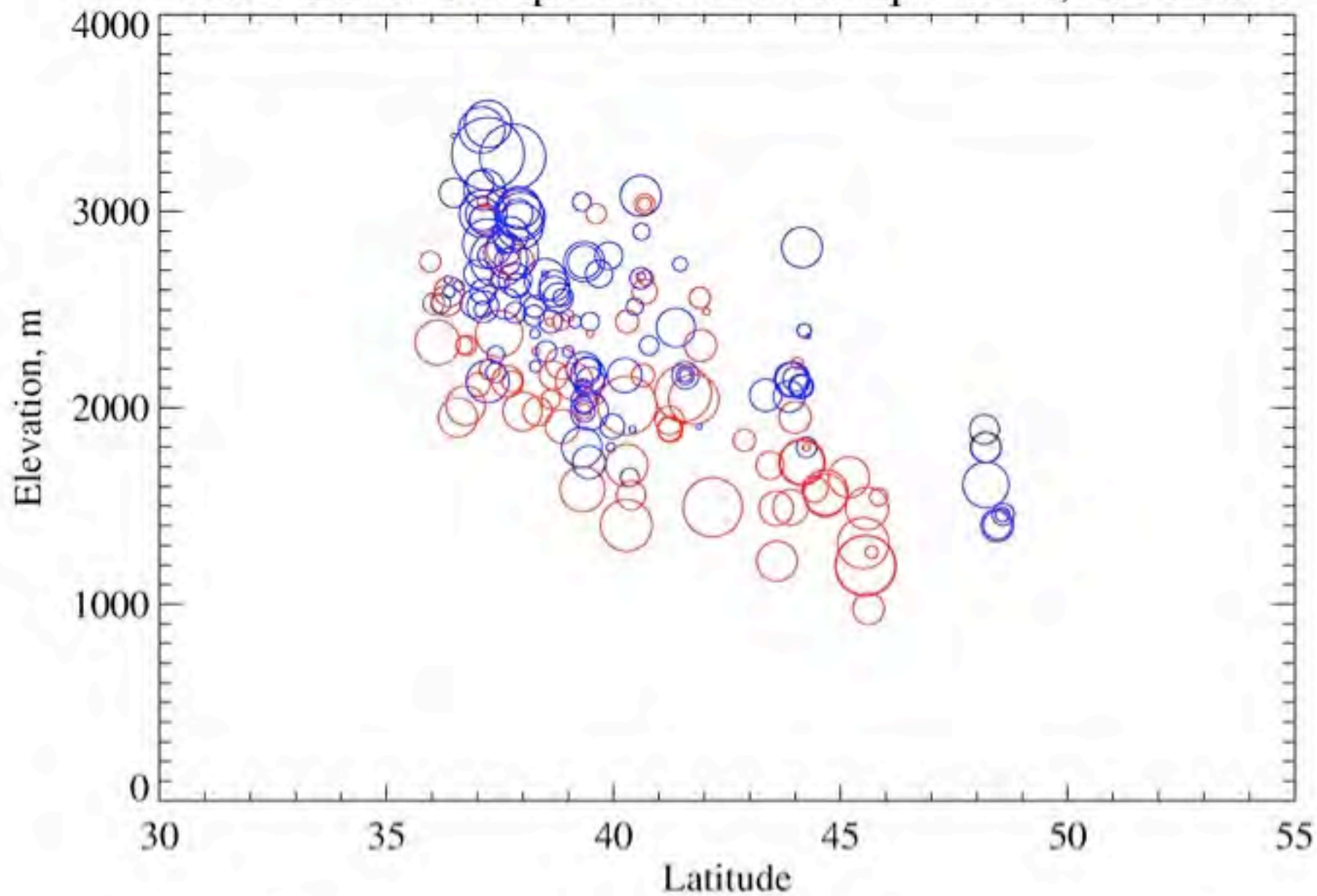
Y-direction: temp

Coldest locations
insensitive to temperature
Cascades very sensitive

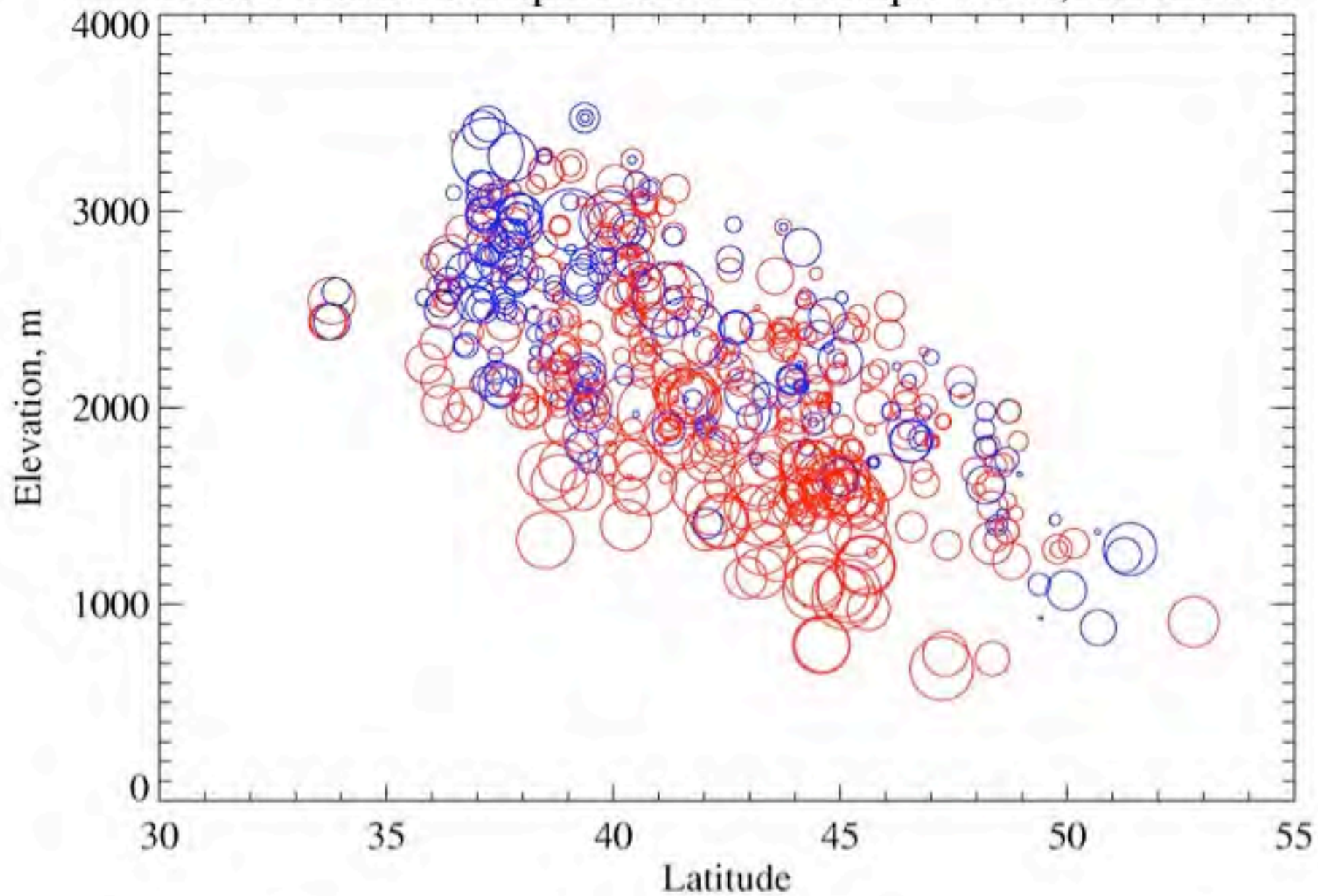
1950-1997 relative trends vs DJF temperature



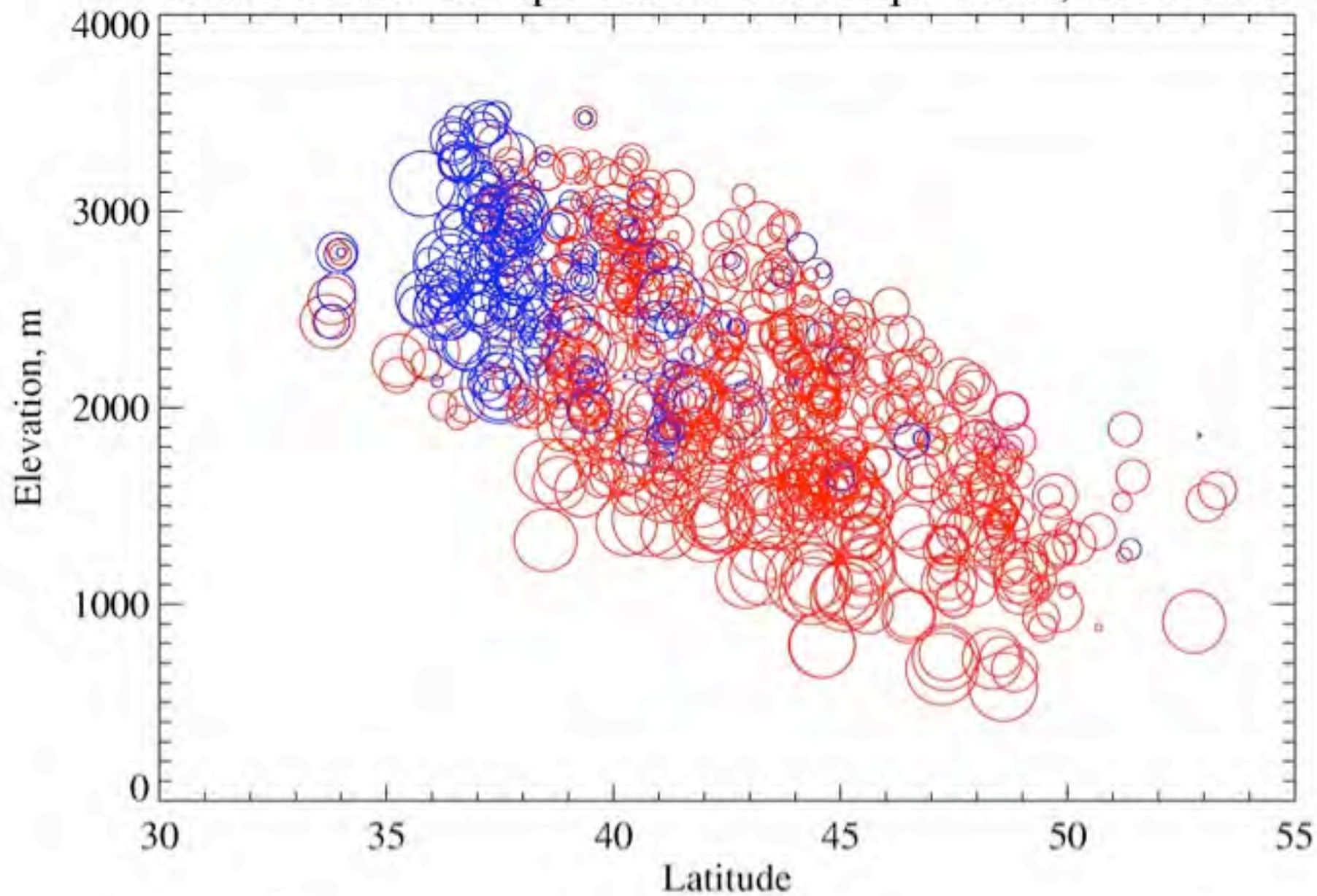
Relative trend in Apr 1 snow water equivalent, 1930-2000



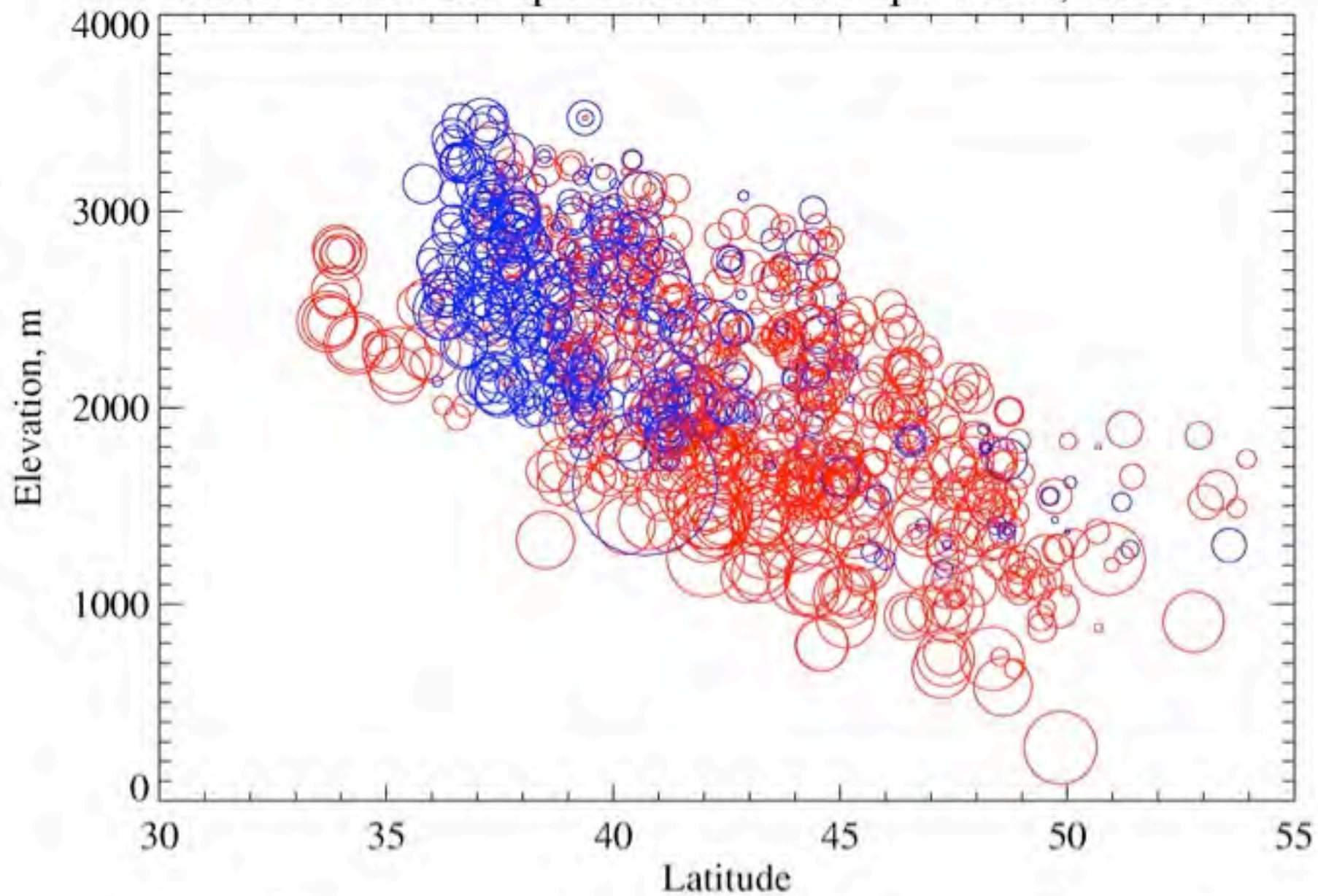
Relative trend in Apr 1 snow water equivalent, 1940-2000



Relative trend in Apr 1 snow water equivalent, 1950-2000

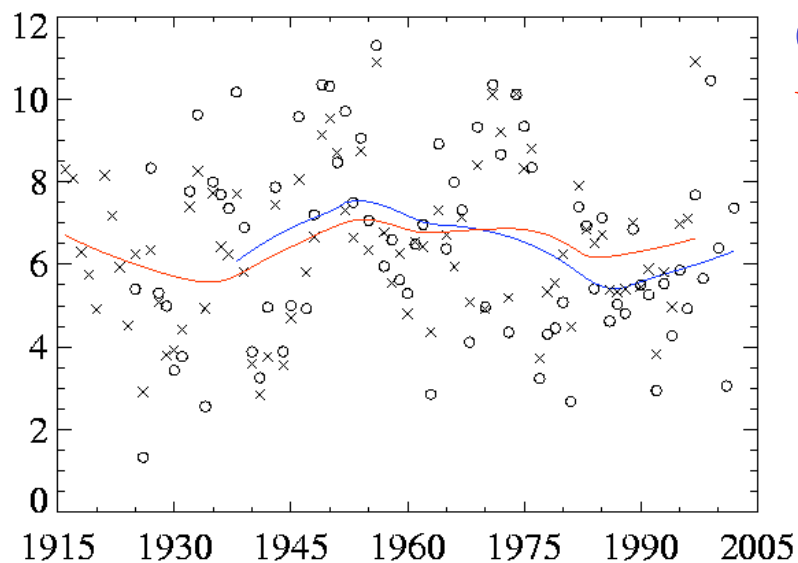


Relative trend in Apr 1 snow water equivalent, 1960-2000

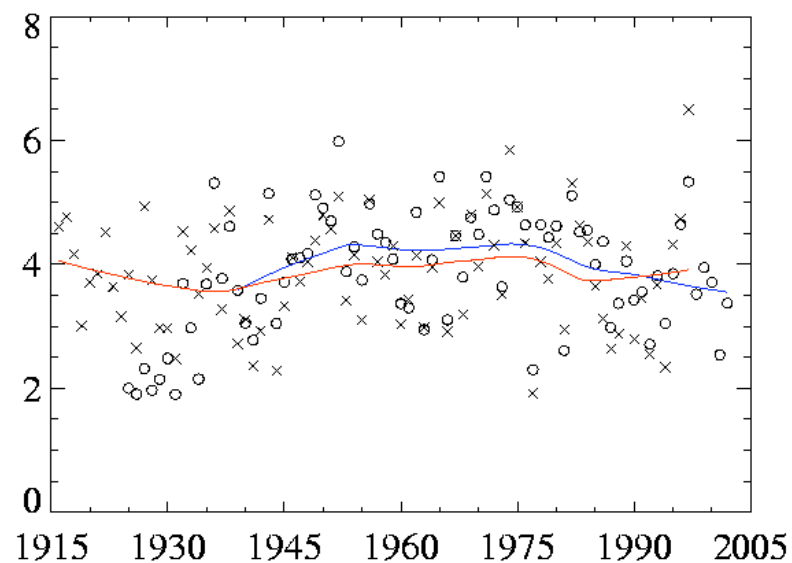


Regional average April 1 SWE

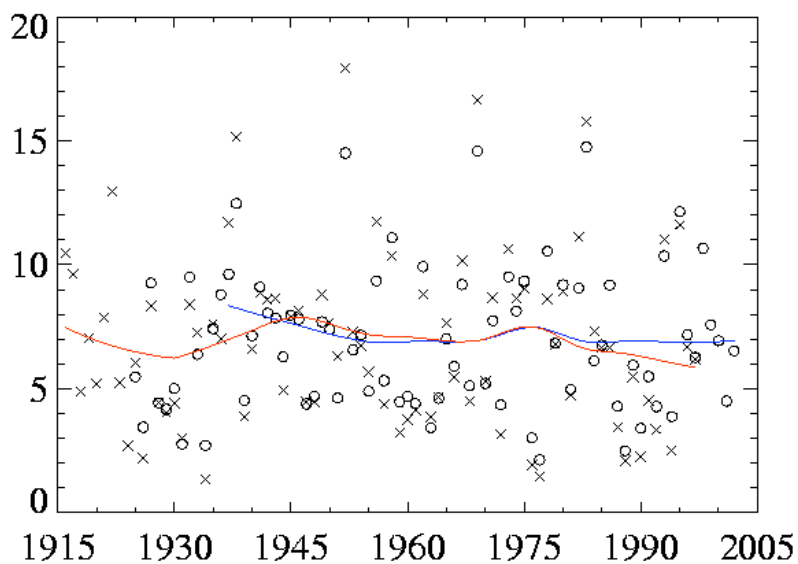
a. Cascades



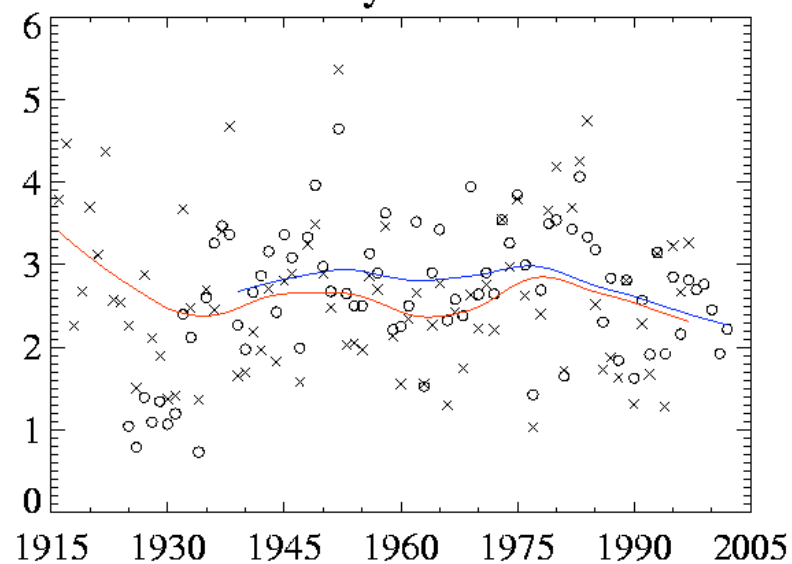
b. Rockies

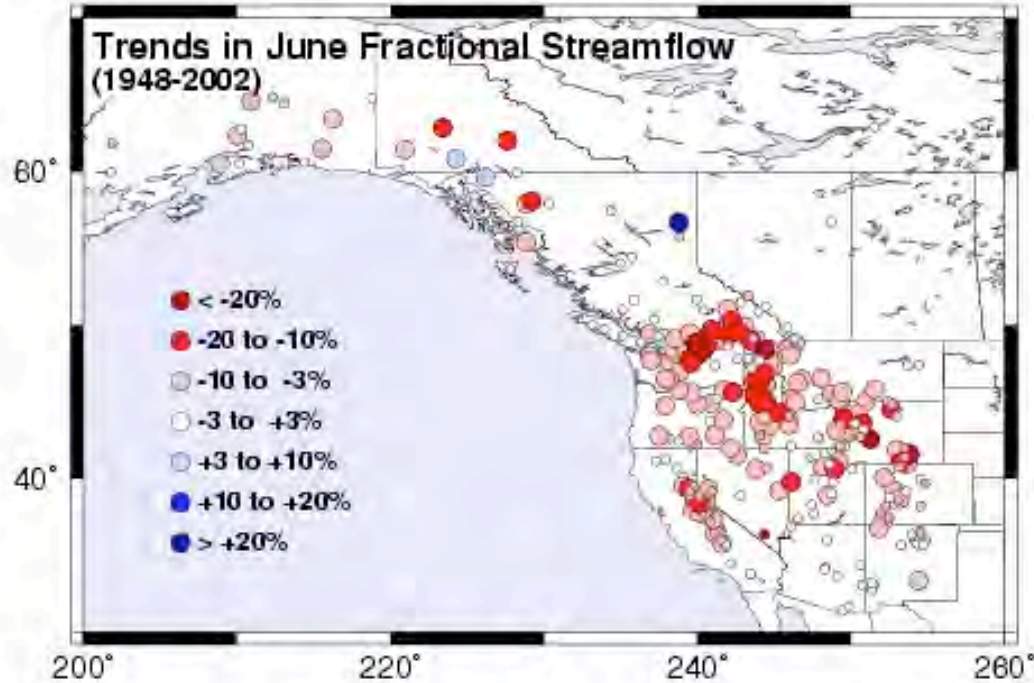
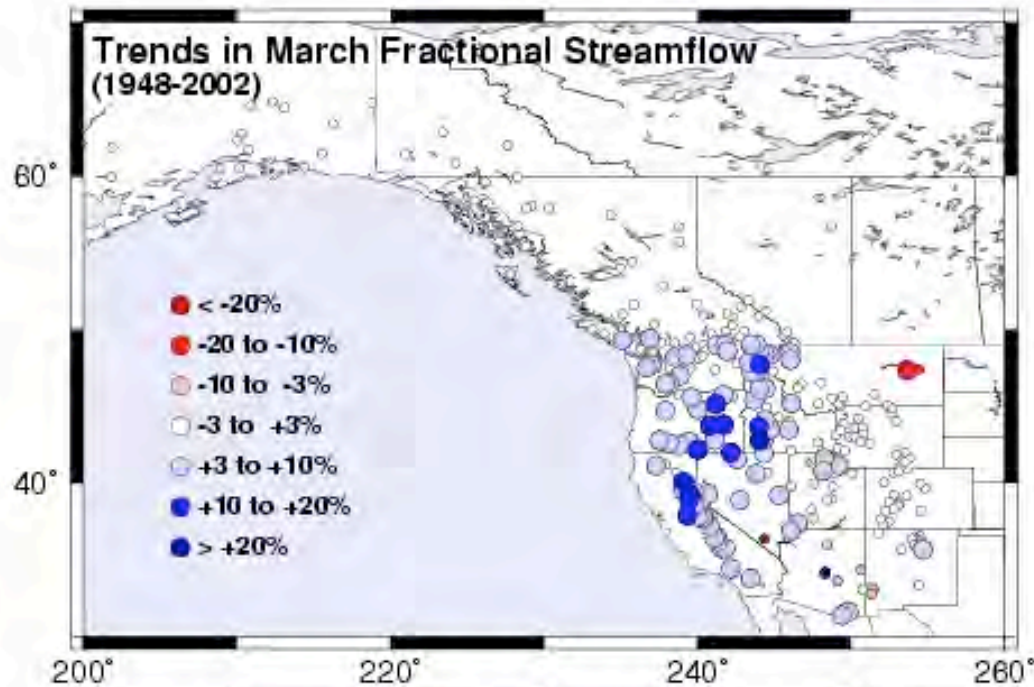


c. California



d. Dry interior





As the West warms,
winter flows rise and
summer flows drop

Figure by Iris Stewart,
Scripps Inst. of Oceanog.
(UC San Diego)

Conclusions

- Temperature has shown persistent trends, precipitation has not; future: more of the same (slight increase in winter precip)
- Declines in snowpack have been pronounced at moderate elevations except where precipitation has dominated

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